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(54) **SLANTED VIAS FOR ELECTRICAL CIRCUITS ON CIRCUIT BOARDS AND OTHER SUBSTRATES**

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(57)

**ABSTRACT**

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(58) **Field of Classification Search** ..... 174/262, 174/263, 264, 265, 266; 361/792, 793, 794, 361/795

See application file for complete search history.

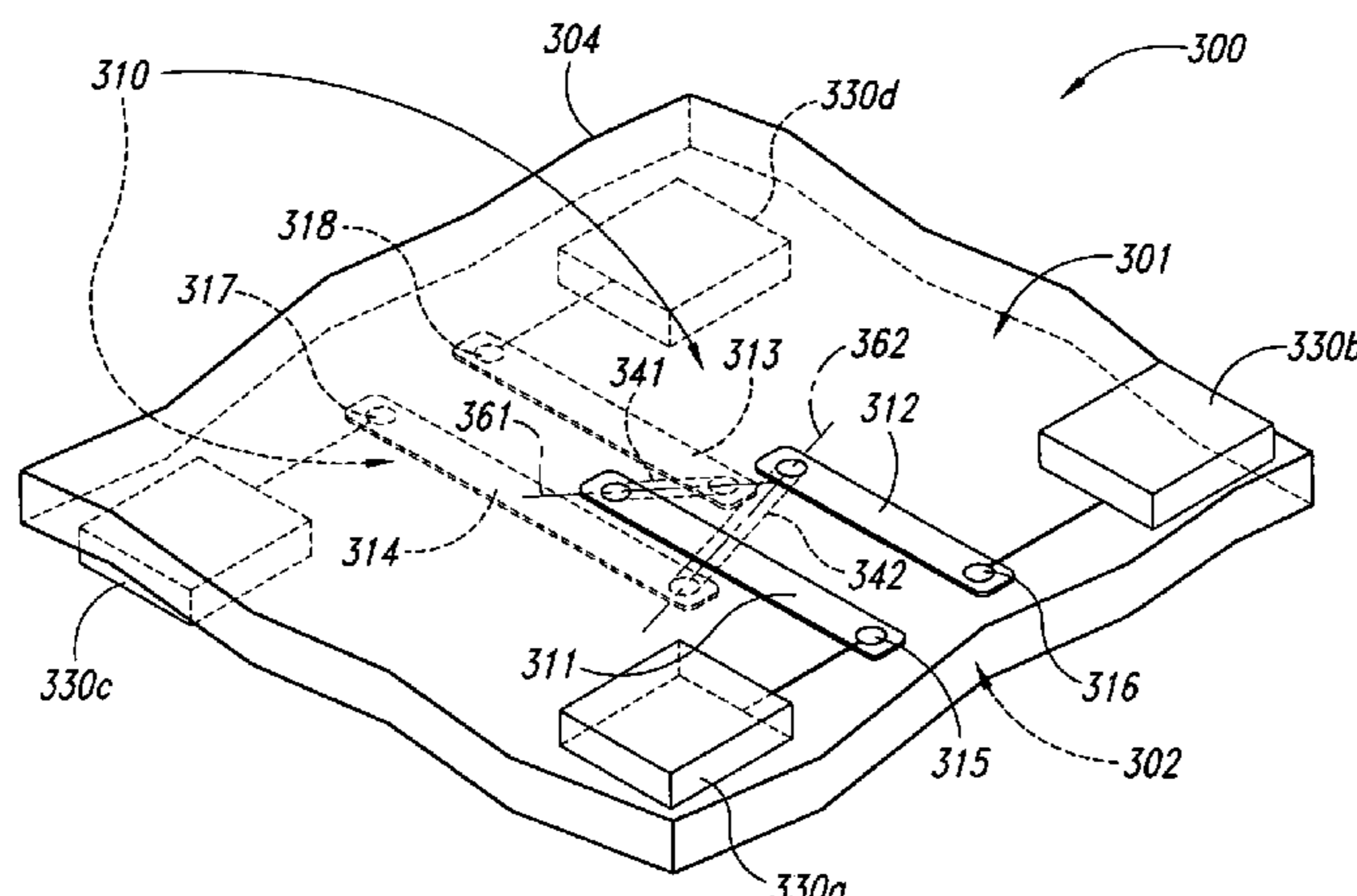
Circuit boards, microelectronic devices, and other apparatuses having slanted vias are disclosed herein. In one embodiment, an apparatus for interconnecting electronic components includes a dielectric portion having a first surface and a second surface. A first terminal is disposed on the first surface of the dielectric portion for connection to a first electronic component. A second terminal is disposed on the second surface of the dielectric portion for connection to a second electronic component. The apparatus further includes a passage extending through the dielectric portion along a longitudinal axis oriented at an oblique angle relative to the first surface. The passage is at least partially filled with conductive material electrically connecting the first terminal to the second terminal.

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**14 Claims, 3 Drawing Sheets**



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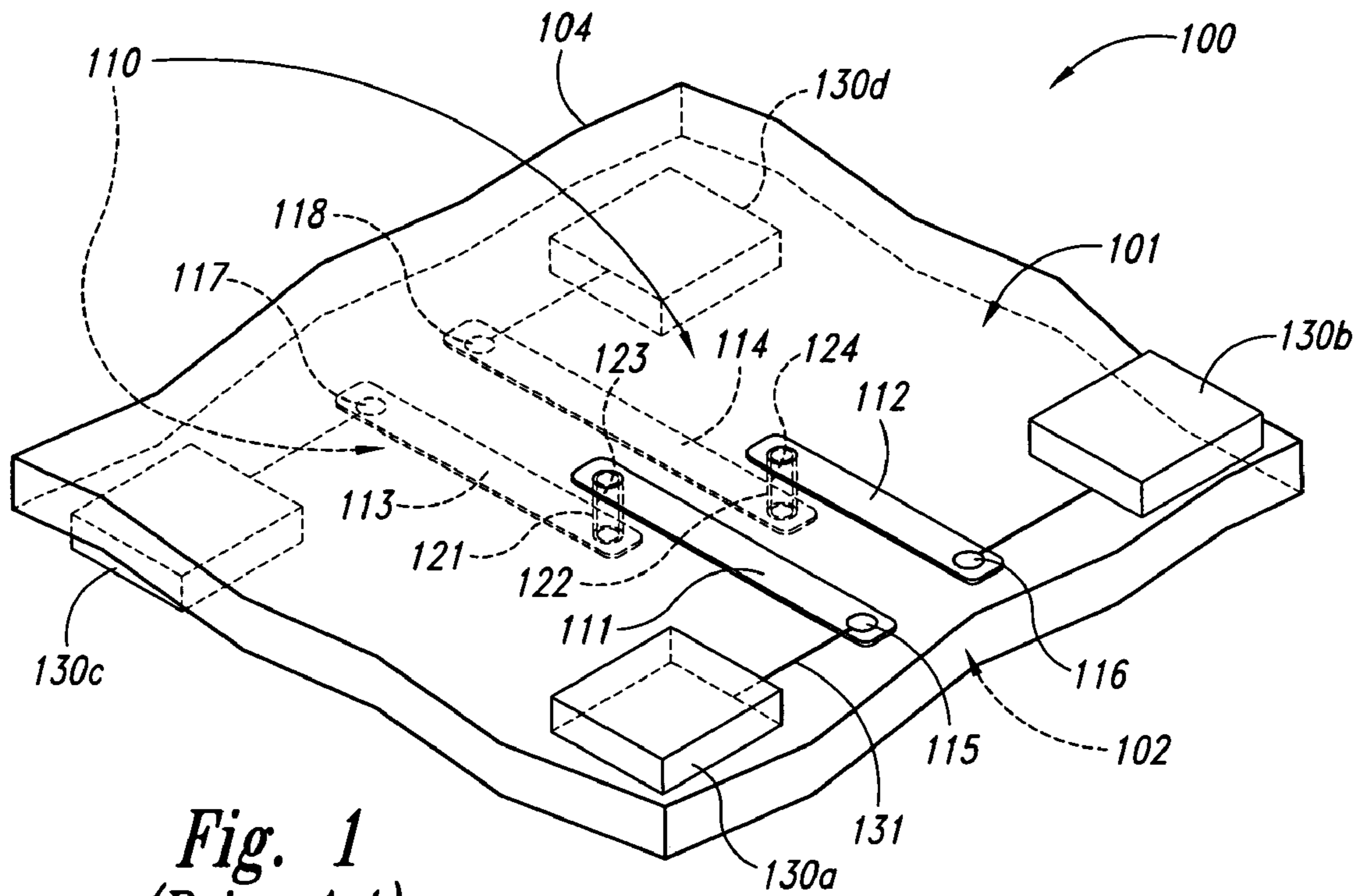
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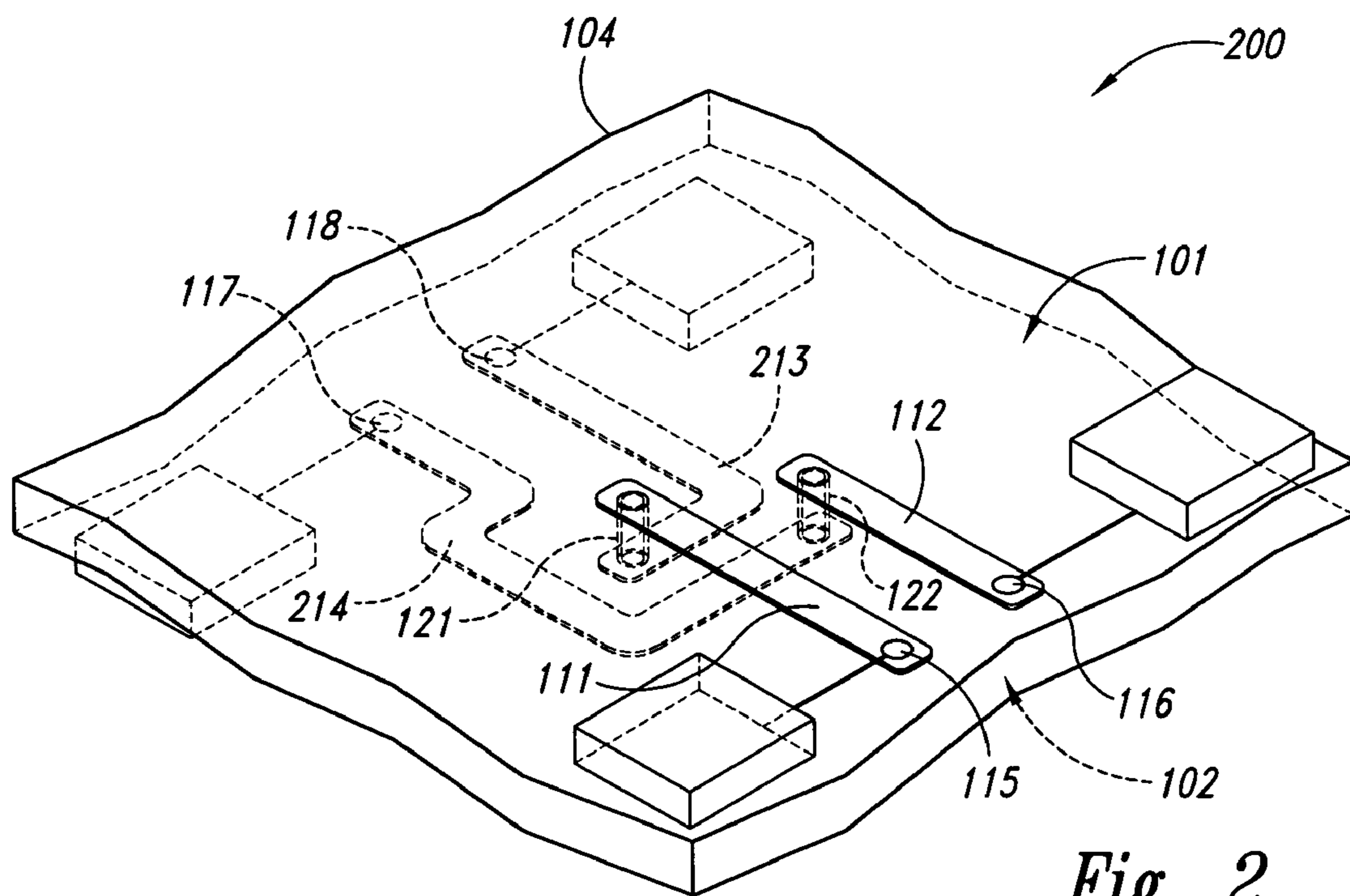
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*Fig. 1*  
*(Prior Art)*



*Fig. 2*  
*(Prior Art)*

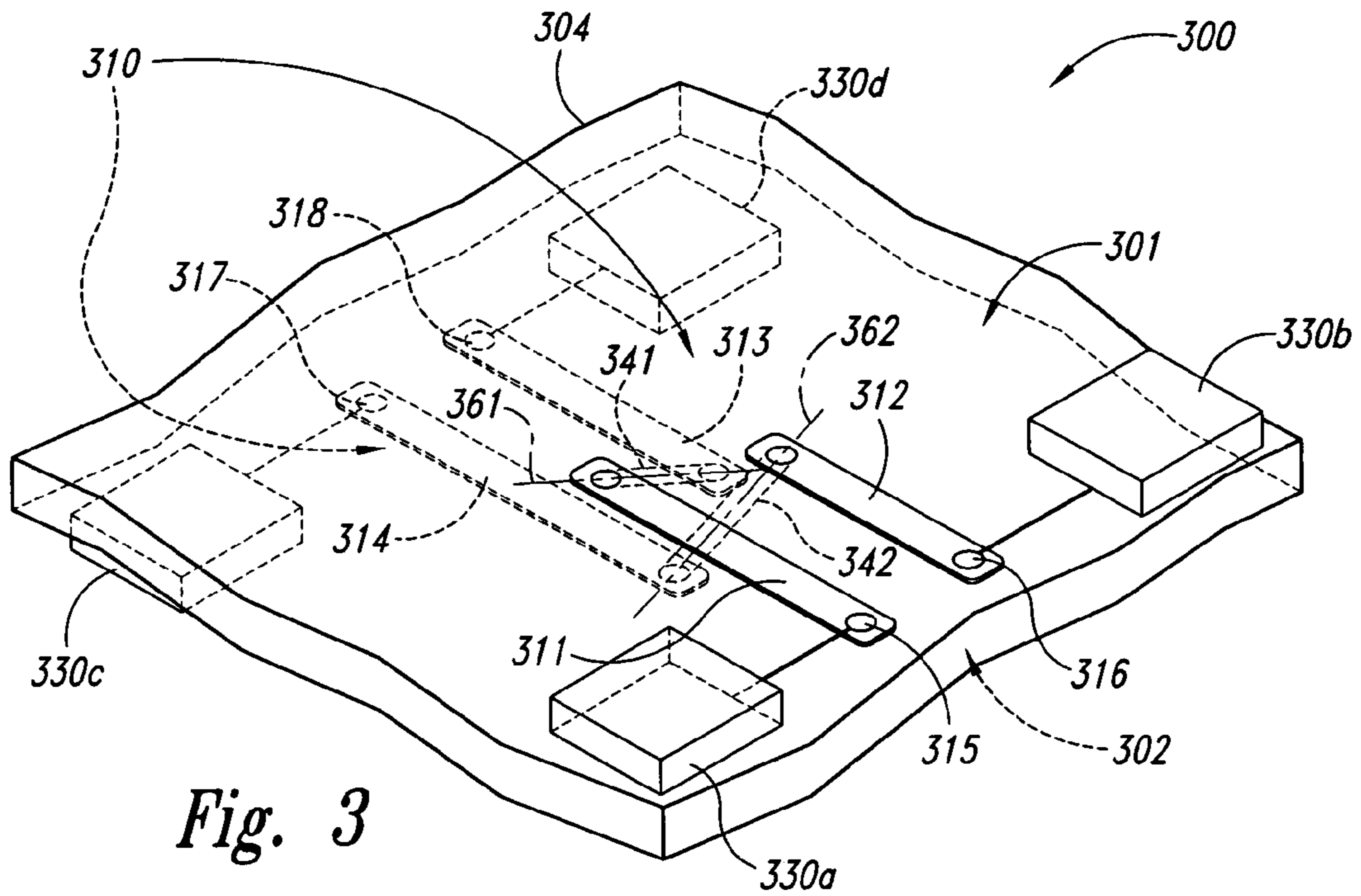


Fig. 3

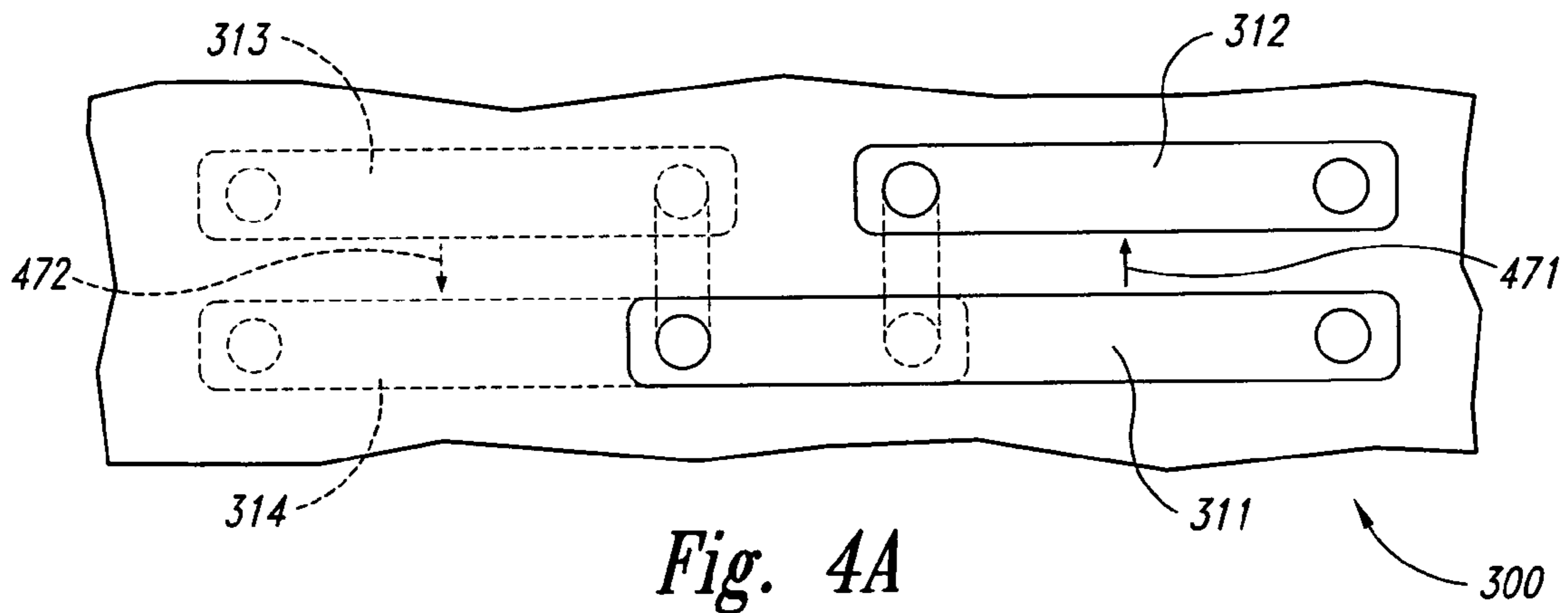


Fig. 4A

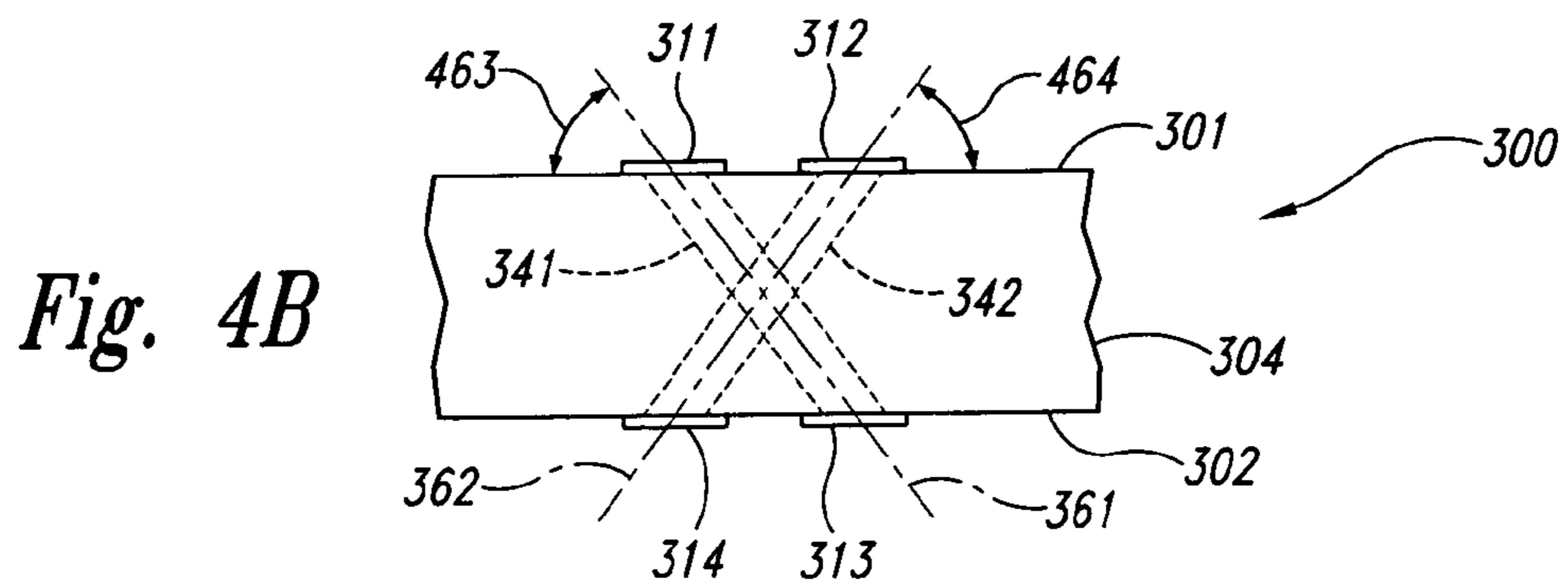
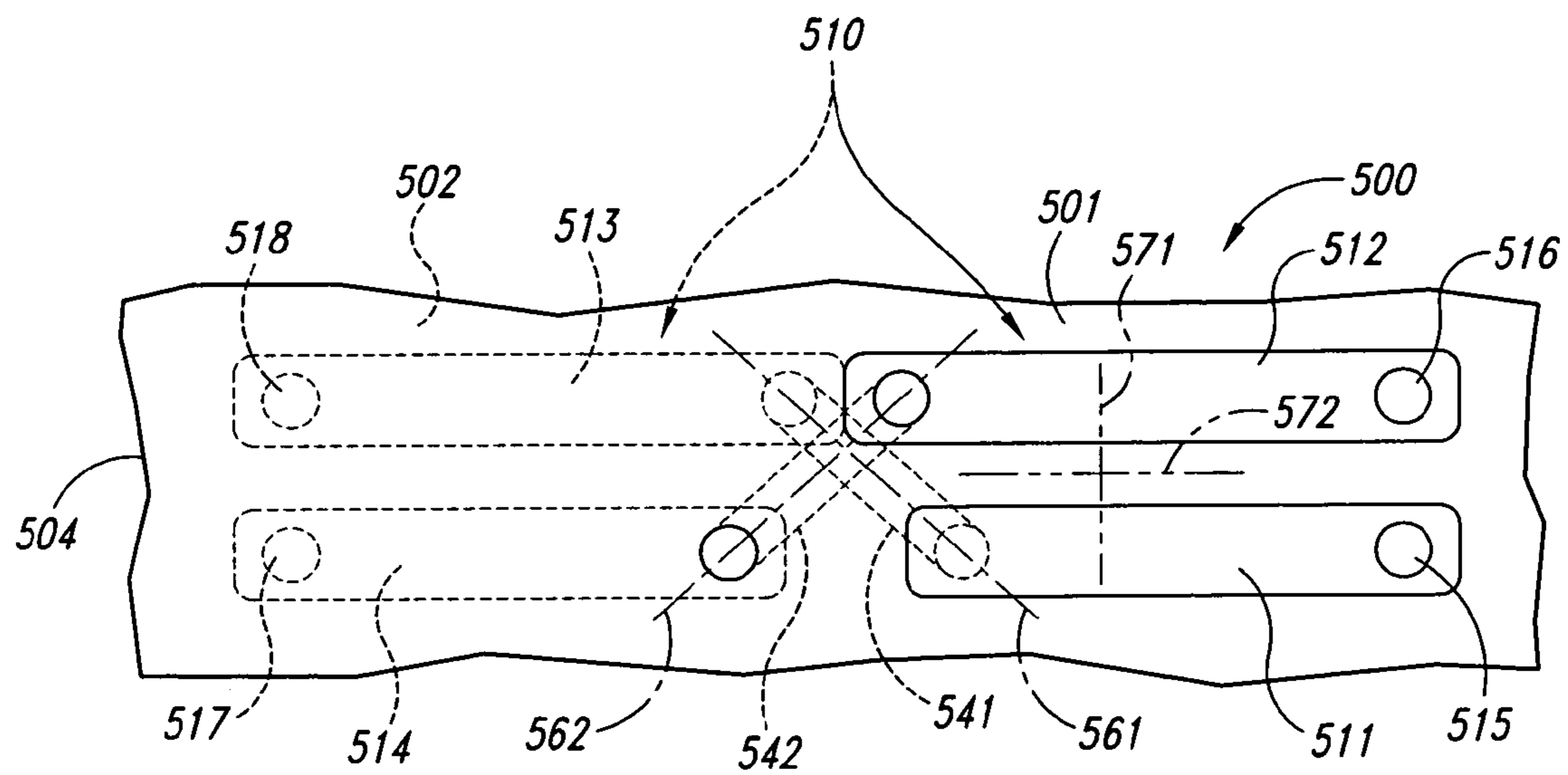
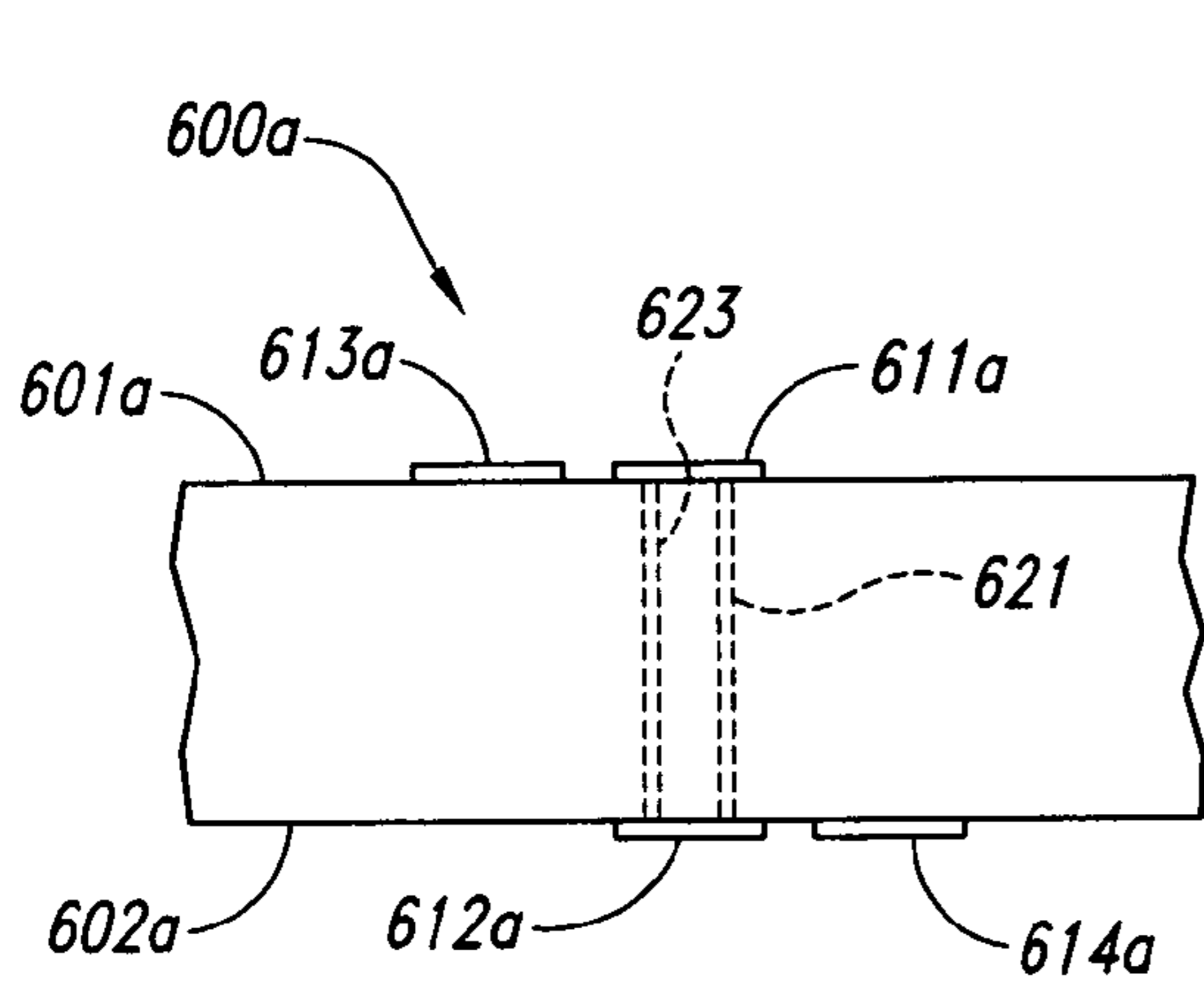


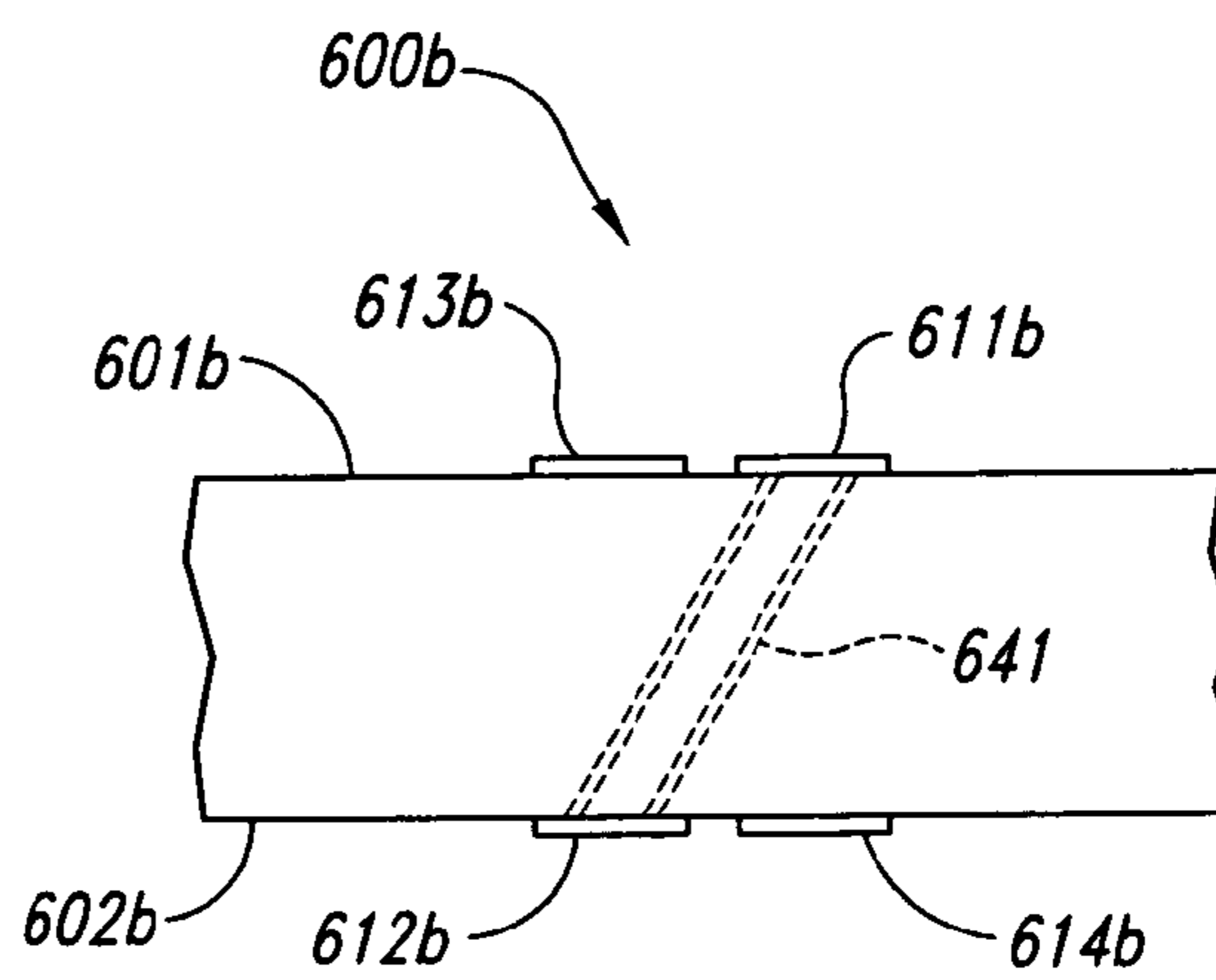
Fig. 4B



*Fig. 5*



*Fig. 6A*  
*(Prior Art)*



*Fig. 6B*

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## SLANTED VIAS FOR ELECTRICAL CIRCUITS ON CIRCUIT BOARDS AND OTHER SUBSTRATES

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 10/927,760 filed Aug. 27, 2004, now U.S. Pat. No. 7,083,425 which claims foreign priority benefits of Singapore Application No. 200405514-1 filed Aug. 27, 2004, both of which are incorporated herein by reference in their entireties.

### TECHNICAL FIELD

The following disclosure relates generally to electrical circuits on circuit boards, microelectronic devices, and other substrates and, more particularly, to conductive vias used with such circuits.

### BACKGROUND

Printed circuit boards (PCBs), printed wire boards (PWBs), and similar structures typically include a plurality of conductive lines or traces superimposed or "printed" on one or more sides of a non-conductive substrate. Electronic components can be mounted to the substrate and interconnected by means of wire bonds and/or solder attachments to the conductive lines. FIG. 1, for example, is an isometric view illustrating a portion of a PCB 100 configured in accordance with the prior art. The PCB 100 supports a plurality of electronic components 130 (illustrated schematically in FIG. 1 and identified individually as electronic components 130a-d). The electronic components 130 can include processing devices, routing devices, memory devices and other types of electronic devices typically found on conventional circuit boards in computers, cell phones, personal data assistants, and other electronic products.

The electronic components 130 are mounted to a non-conductive substrate 104 and are interconnected by means of an electrical circuit 110. The electrical circuit 110 includes a first conductive line 111 and a second conductive line 112 disposed on a first surface 101 of the non-conductive substrate 104. The electrical circuit 110 further includes a third conductive line 113 and a fourth conductive line 114 disposed on a second surface 102 of the non-conductive substrate 104 opposite to the first surface 101. The first conductive line 111 is electrically connected to the third conductive line 113 by conductive material 123 in a first passage 121 that extends vertically through the non-conductive substrate 104 from the first conductive line 111 to the third conductive line 113. The second conductive line 112 is similarly connected to the fourth conductive line 114 by conductive material 124 in a second passage 122 that extends vertically through the non-conductive substrate 104 from the second conductive line 112 to the fourth conductive line 114. The passages 121 and 122 are often referred to by those in the art as "plated through-holes" or "vias."

Each of the conductive lines 111-114 includes a corresponding contact or terminal (identified individually as a first terminal 115, a second terminal 116, a third terminal 117, and a fourth terminal 118, respectively). The first electronic component 130a is electrically connected to the first terminal 115 by a wire bond or solder attachment 131 (shown schematically). The second electronic component 130b, the third electronic component 130c, and the fourth electronic component

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130d are electrically connected to the second terminal 116, the third terminal 117, and the fourth terminal 118, respectively, in a similar manner.

In the prior art example of FIG. 1, the conductive path between the first terminal 115 and the third terminal 117, and the conductive path between the second terminal 116 and the fourth terminal 118, are relatively straight and direct. In practice, however, it is not uncommon for the paths between two or more pairs of corresponding terminals to cross each other.

FIG. 2 is an isometric view illustrating a portion of a prior art PCB 200 in which the paths between two pairs of corresponding terminals cross each other. Many of the features of the PCB 200 are at least generally similar in structure and function to corresponding features of the PCB 100 described above. For example, the PCB 200 includes the first conductive line 111 and the second conductive line 112 disposed on the first surface 101 of the non-conductive substrate 104. The PCB 200 also includes the first passage 121 and the second passage 122 extending vertically through the non-conductive substrate 104. In contrast to the PCB 100 described above, however, in the example of FIG. 2 the first terminal 115 is electrically connected to the fourth terminal 118, and the second terminal 116 is electrically connected to the third terminal 117.

To accommodate the change in terminals, the PCB 200 includes a third conductive line 213 extending from the first passage 121 to the fourth terminal 118, and a fourth conductive line 214 extending from the second passage 122 to the third terminal 117. As illustrated in FIG. 2, the third and fourth conductive lines 213 and 214 describe somewhat indirect paths between the passages 121 and 122 and the respective terminals. Specifically, the third conductive line 213 jogs away from the third terminal 117 to provide clearance for the fourth conductive line 214, and the fourth conductive line 214 routes around the first passage 121 before proceeding toward the third terminal 117.

There are a number of shortcomings associated with indirect conductive lines such as those described above with reference to FIG. 2. One shortcoming is that the increased line length increases the resistance and inductance in the circuit, thereby increasing the susceptibility to undesirable noise-related effects such as cross-talk. Another shortcoming is that the increased line length can reduce signal strength and increase signal delay. A further shortcoming is the additional material and complexity associated with manufacturing jogged, rather than straight, conductive lines.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially schematic isometric view of a portion of a printed circuit board configured in accordance with the prior art.

FIG. 2 is a partially schematic isometric view of another printed circuit board configured in accordance with the prior art.

FIG. 3 is a partially schematic isometric view of a portion of an apparatus having slanted vias configured in accordance with an embodiment of the invention.

FIG. 4A is a partially hidden top view, and FIG. 4B is a partially hidden end view, of the apparatus of FIG. 3.

FIG. 5 is a partially hidden top view of an apparatus having slanted vias configured in accordance with another embodiment of the invention.

FIG. 6A is a partially hidden end view of a circuit board having a vertical via configured in accordance with the prior



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art, and FIG. 6B is a partially hidden end view of a circuit board having a slanted via configured in accordance with an embodiment of the invention.

## DETAILED DESCRIPTION

### A. Overview

The following disclosure describes several embodiments of printed circuit boards, printed wiring boards, and other substrates and apparatuses for interconnecting electronic components. One aspect of the invention is directed toward an apparatus for interconnecting electronic components that includes a dielectric portion having a first surface opposite to a second surface. A first terminal is disposed on the first surface of the dielectric portion for connection to a first electronic component. A second terminal is disposed on the second surface of the dielectric portion for connection to a second electronic component. The apparatus further includes a passage extending through the dielectric portion along a longitudinal axis oriented at an oblique angle relative to the first surface. The passage is at least partially filled with conductive material to electrically connect the first terminal to the second terminal.

Another aspect of the invention is directed toward a method for manufacturing an apparatus for interconnecting electronic components. In one embodiment, the method includes forming a first conductive line on a first surface of a dielectric substrate, and forming a second conductive line on a second surface of the dielectric substrate facing opposite to the first surface. The method further includes extending a passage through the dielectric substrate from the first conductive line to the second conductive line, and at least partially filling the passage with conductive material to electrically connect the first conductive line to the second conductive line. In one aspect of this embodiment, the passage extends through the dielectric substrate along a longitudinal axis oriented at an oblique angle relative to the first surface of the dielectric substrate.

Many specific details of the present invention are described below with reference to circuit boards, such as printed circuit boards and printed wiring boards. The present invention, however, is not limited to such structures. Indeed, the terms “dielectric portion,” “dielectric substrate,” and “non-conductive substrate” as used throughout this disclosure do not refer solely to circuit board structures. To the contrary, these terms refer broadly to other structures upon which and/or in which electrical circuits are formed including, for example, microelectronic devices and packaged microelectronic devices (such as packaged microelectronic devices in stacked-chip and/or flip-chip arrangements). Accordingly, the terms listed above refer not only to circuit board substrates such as composite laminates, but also refer to microelectronic workpieces such as semiconductor wafers (e.g., silicon or gallium arsenide wafers), glass substrates, ceramic substrates, and other types of insulated substrates known to those of ordinary skill in the art.

Specific details of several embodiments of the invention are described below with reference to circuit boards and other apparatuses in order to provide a thorough understanding of such embodiments. Other details describing well-known structures often associated with such apparatuses are not set forth below to avoid unnecessarily obscuring the description of the various embodiments. Those of ordinary skill in the relevant art will understand, however, that the invention may have other embodiments that include other elements in addi-

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tion to those described below. Alternatively, the invention may have still further embodiments that lack one or more of the elements described below.

In the Figures, identical reference numbers identify identical or at least generally similar elements. To facilitate the discussion of any particular element, the most significant digit or digits of any reference number refer to the Figure in which that element is first introduced. For example, element **310** is first introduced and discussed with reference to FIG. **3**.

### B. Embodiments of Electrical Circuits Having Slanted Vias

FIG. **3** is a partially schematic isometric view of a portion of an apparatus **300** having an electrical circuit **310** with slanted vias configured in accordance with an embodiment of the invention. In one embodiment, the apparatus **300** can represent a circuit board, such as a printed circuit board (PCB) or a printed wiring board (PWB). In other embodiments, the apparatus **300** can represent other structures having electrical circuits for interconnecting various types of electronic components. Such structures can include, for example, microelectronic workpieces and packaged microelectronic devices having electrical circuits composed of electrical traces, wire bonds, bond pads, vias, etc., for connecting integrated circuits. In further embodiments, the apparatus **300** can represent yet other structures having electrical circuits.

In the illustrated embodiment, the electrical circuit **310** includes a first conductive line **311** and a second conductive line **312** disposed on a first surface **301** of a non-conductive substrate or dielectric portion **304**. The electrical circuit **310** further includes a third conductive line **313** and a fourth conductive line **314** disposed on a second surface **302** of the dielectric portion **304** facing opposite to the first surface **301**. A first contact or terminal **315** electrically connects a first electronic component **330a** to the first conductive line **311**, and a second terminal **316** electrically connects a second electronic component **330b** to the second conductive line **312**. Similarly, a third terminal **317** electrically connects a third electronic component **330c** to the fourth conductive line **314**, and a fourth terminal **318** electrically connects a fourth electronic component **330d** to the third conductive line **313**.

In one aspect of this embodiment, a first slanted via **341** (hereinafter the first “passage” **341**) extends through the dielectric portion **304** along a first longitudinal axis **361**, and a second slanted via **342** (hereinafter the second “passage” **342**) extends through the dielectric portion **304** along a second longitudinal axis **362**. The first longitudinal axis **361** intersects the first conductive line **311** and the third conductive line **313**, and forms an oblique angle relative to the first surface **301** of the dielectric portion **304**. The second longitudinal axis **362** intersects the second conductive line **312** and the fourth conductive line **314**, and also forms an oblique angle relative to the first surface **301** of the dielectric portion **304**. The first passage **341** is at least partially filled with conductive material **343** to electrically connect the first conductive line **311** to the third conductive line **313**. Similarly, the second passage **342** is at least partially filled with conductive material **344** to electrically connect the second conductive line **312** to the fourth conductive line **314**.

The apparatus **300** can be manufactured in a number of different ways and with a number of different materials depending on the particular application or the intended use. In a circuit board embodiment, for example, the dielectric portion **304** can include a glass-reinforced polymer laminate (e.g., FR-4) having a copper foil laminated to both the first

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surface **301** and the second surface **302**. The copper foil forms the basis of the conductive lines **311-314**. The passages **341** and **342** can be formed through the laminate by mechanical drilling, laser drilling (e.g., “mask image” drilling or “conformal image” drilling), or other suitable methods known in the art.

The passages **341** and **342** are filled with copper to electrically couple (a) the first conductive line **311** to the third conductive line **313**, and (b) the second conductive line **312** to the fourth conductive line **314**. For example, after the passages **341** and **342** have been formed and cleaned, copper can be electrolessly deposited over the copper foil and onto the inner walls of the passages **341** and **342** to form a seed layer for bulk copper deposition into the passages **341** and **342**. The seed layer and copper foil on the first surface **301** and the second surface **302** are then covered with a mask using a suitable image transfer process. The passages **341** and **342** are then filled with a suitable conductive material by electroplating the conductive material on the walls of the passages **341** and **342**. The conductive material also plates onto the exposed areas of copper on the first and second surfaces **301** and **302** to form the conductive lines **311-314**. The conductive material can include a number of different metals such as copper, tin, lead, etc., known in the art. After electroplating, the mask layer is stripped and the unwanted metallic material on the first and second surfaces **301** and **302** around the conductive lines **311-314** is removed by a suitable process, such as chemical etching. At this point in the manufacturing process, the electronic components **330a-d** can be electrically connected to the corresponding terminals **315-318**, respectively, using wire bonds, solder connections, or other suitable methods known in the art.

Although the method of manufacturing described above may be suitable for some embodiments of the present invention, other manufacturing processes can be used for other embodiments without departing from the spirit or scope of the present disclosure. For example, in other embodiments of the invention, the apparatus **300** can be a portion of an electronic device, such as a microelectronic device. In a microelectronic device, the dielectric portion **304** can be a portion of a silicon wafer that contains one or more integrated circuits (i.e., a “die” or “chip”). In such embodiments, the slanted vias of the present invention can be used as electrical conduits for connecting two or more dies in, for example, a stacked-chip or flip-chip arrangement. Accordingly, the slanted vias of the present invention are not limited to circuit board applications, but extend to other apparatuses for interconnecting electronic components at both the circuit board and microelectronic device level.

FIG. **4A** is a partially hidden top view of the apparatus **300** of FIG. **3**, and FIG. **4B** is a partially hidden end view of the apparatus **300** of FIG. **3**, for the purpose of further illustrating the spatial relationships between the various features of the electrical circuit **310**. As FIG. **4A** illustrates, the second conductive line **312** is offset from the first conductive line **311** in a first direction **471** on the first surface **301** of the dielectric portion **304**. The fourth conductive line **314** is offset from the third conductive line **313** on the second surface **302** in a second direction **472** that is opposite to the first direction **471**. Further, in the illustrated embodiment the fourth conductive line **314** is at least approximately aligned with the first conductive line **311**, and the third conductive line **313** is at least approximately aligned with the second conductive line **312**. As FIG. **4B** illustrates, the first longitudinal axis **361** of the first passage **341** passes through the first conductive line **311** and the third conductive line **313**, and forms a first oblique angle **463** relative to the first surface **301** of the dielectric

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portion **304**. Similarly, the second longitudinal axis **362** of the second passage **342** passes through the second conductive line **312** and the fourth conductive line **314**, and forms a second oblique angle **464** relative to the first surface **301** of the dielectric portion **304**.

FIGS. **3-4B** together illustrate that slanting the passages **341** and **342** enables the third conductive line **313** and the fourth conductive line **314** to be at least generally straight and direct without any jogs. One advantage of this feature over the jogged conductive lines **213** and **214** described above with reference to prior art FIG. **2** is that the direct paths of the present invention can increase processing speed and reduce the electrical resistance and inductance in the circuit, thereby decreasing the susceptibility to undesirable noise-related effects during signal transmission. A further advantage of this feature is that direct paths require less material and are easier to manufacture than jogged paths. In addition, slanted vias offer a useful design alternative when dealing with complicated circuit boards having a large number of conductive lines compressed into a small area.

The spatial arrangements of the features illustrated in FIGS. **3-4B** are merely representative of one particular embodiment of the invention. Accordingly, the present invention is not limited to the particular arrangements illustrated in these Figures. To the contrary, the slanted vias of the present invention can be used in a multitude of other electrical circuit arrangements having more or fewer conductive lines, terminals, and/or via elements than those shown in FIGS. **3-4B**.

FIG. **5** is a partially hidden top view of an apparatus **500** having an electrical circuit **510** with slanted vias configured in accordance with another embodiment of the invention. Many features of the apparatus **500** are at least generally similar in structure and function to the corresponding features of the apparatus **300** described in detail above with reference to FIGS. **3-4B**. For example, the apparatus **500** includes a dielectric portion **504** having a first surface **501** and an opposing second surface **502**. A first conductive line **511** is disposed on the first surface **501** adjacent to a second conductive line **512**. Similarly, a third conductive line **513** is disposed on the second surface **502** adjacent to a fourth conductive line **514**. Each of the conductive lines **511-514** includes a corresponding terminal **515-518**, respectively. In the illustrated embodiment, the first conductive line **511** is electrically connected to the third conductive line **513** by a first passage **541** extending through the dielectric portion **504** along a first longitudinal axis **561**. Similarly, the second conductive line **512** is electrically connected to the fourth conductive line **514** by a second passage **542** extending through the dielectric portion **504** along a second longitudinal axis **562**.

The apparatus **500** of FIG. **5** may offer certain advantages over the apparatus **300** of FIGS. **3-4B** because the overall lengths of the conductive paths between the terminals **515** and **518**, and between the terminals **516** and **517**, are shorter on the apparatus **500**. As illustrated in FIG. **5**, the paths are shorter because the passages **541** and **542** are not only slanted along a first axis **571** toward the respective conductive lines, but are also slanted along a second axis **572** toward the respective terminals. By slanting the passages **541** and **542** in this manner, the conductive paths can be further shortened over the embodiment illustrated in FIGS. **3-4B**. Accordingly, those of ordinary skill in the art will appreciate that the various different slant angles can be incorporated into a particular circuit design without departing from the spirit or scope of the present disclosure. The choice of slant angle will depend on the particular application and the particular design constraints.

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FIG. 6A is a partially hidden end view of an apparatus **600a** configured in accordance with the prior art, and FIG. 6B is a partially hidden end view of an apparatus **600b** configured in accordance with an embodiment of the present invention. Together, FIGS. 6A-B illustrate the flexibility offered by slanted vias from a design perspective. Referring first to FIG. 6A, the prior art apparatus **600a** includes a first conductive line **611a** electrically connected to a second conductive line **612a** by a vertical passage **621** at least partially filled with a conductive material **623**. The apparatus **600a** further includes a third conductive line **613a** positioned adjacent to the first conductive line **611a**, and a fourth conductive line **614a** positioned adjacent to the second conductive line **612a**. As FIG. 6A illustrates, the vertical passage **621** precludes positioning the fourth conductive line **614a** directly beneath the first conductive line **611a**, and positioning the third conductive line **613a** directly above the second conductive line **612a**, should either of those positions be desired.

Referring next to FIG. 6B, the apparatus **600b** configured in accordance with the present invention includes a first conductive line **611b** electrically connected to a second conductive line **612b** by a slanted passage **641** at least partially filled with conductive material **643**. As FIG. 6B illustrates, slanting the passage **641** enables a fourth conductive line **614b** to be positioned directly beneath the first conductive line **611b**, and a third conductive line **613b** to be positioned directly above the second conductive line **612b**, should either of those positions be desired. Further, slanting the passage **641** enables a more efficient arrangement of the four conductive lines **611b-614b** because together they consume a narrower section of the apparatus **600b** than the four conductive lines **611a-614a** consume of the apparatus **600a**.

From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

We claim:

1. An apparatus for interconnecting electronic components, the apparatus comprising:

a dielectric portion having a first surface opposite to a second surface, wherein the dielectric portion carries an integrated circuit;

a first passage formed through the dielectric portion along a first longitudinal axis oriented at an oblique angle relative to the first surface, wherein the first passage is at least partially filled with a first portion of conductive material after forming;

a second passage formed through the dielectric portion along a second longitudinal axis that is non-parallel to the first longitudinal axis, wherein the second longitudinal axis is oriented at an oblique angle relative to the first surface of the dielectric portion, and wherein the second passage is at least partially filled with a second portion of conductive material after forming;

a first terminal disposed on the first surface of the dielectric portion and electrically connected to the integrated circuit;

a second terminal disposed on the second surface of the dielectric portion, wherein the first portion of conductive material at least partially filling the first passage electrically connects the first terminal to the second terminal;

a third terminal disposed on the first surface of the dielectric portion, wherein the third terminal is offset from the first terminal in a first direction; and

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a fourth terminal disposed on the second surface of the dielectric portion, wherein the fourth terminal is offset from the second terminal in a second direction opposite to the first direction, and wherein the second portion of conductive material at least partially filling the second passage electrically connects the third terminal to the fourth terminal.

2. The apparatus of claim 1 wherein

the first terminal is disposed on the first surface of the dielectric portion for connection to a first electronic component, and

the second terminal disposed on the second surface of the dielectric portion for connection to a second electronic component.

3. The apparatus of claim 1 wherein the first terminal is disposed on the first surface of the dielectric portion at a first end of the first passage for connection to a first electronic component, and the second terminal is disposed on the second surface of the dielectric portion at a second end of the first passage for connection to a second electronic component.

4. The apparatus of claim 1 further comprising:

a bond pad disposed on the first surface of the dielectric portion and electrically connected to the integrated circuit,

wherein the first portion of conductive material at least partially filling the first passage electrically connects the bond pad to the second terminal.

5. The apparatus of claim 1 comprising:

a bond pad disposed on the first surface of the dielectric portion and electrically connected to the integrated circuit,

wherein the first portion of conductive material at least partially filling the first passage electrically connects the bond pad to the second terminal; and

a microelectronic die electrically connected to the second terminal.

6. The apparatus of claim 1 wherein

the first terminal is disposed on the first surface of the dielectric portion for connection to a first electronic component, and

the second terminal disposed on the second surface of the dielectric portion for connection to a second electronic component, and wherein the apparatus further comprises:

a first conductive line disposed on the first surface of the dielectric portion and connecting the first terminal to the first portion of conductive material in the first passage; and

a second conductive line disposed on the second surface of the dielectric portion and connecting the second terminal to the first portion of conductive material in the first passage.

7. The apparatus of claim 1, further comprising:

a first conductive line disposed on the first surface of the dielectric portion and connecting the first terminal to the first portion of conductive material in the first passage;

a second conductive line disposed on the second surface of the dielectric portion and connecting the second terminal to the first portion of conductive material in the first passage;

a third conductive line disposed on the first surface of the dielectric portion and connecting the third terminal to the second portion of conductive material in the second passage; and

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a fourth conductive line disposed on the second surface of the dielectric portion and connecting the fourth terminal to the second portion of conductive material in the second passage.

**8.** The apparatus of claim 1, further comprising:

a first conductive line disposed on the first surface of the dielectric portion and connecting the first terminal to the first portion of conductive material in the first passage;

a second conductive line disposed on the second surface of the dielectric portion and connecting the second terminal to the first portion of conductive material in the first passage;

a third conductive line disposed on the first surface of the dielectric portion in alignment with the second conductive line, wherein the third conductive line connects the third terminal to the second portion of conductive material in the second passage; and

a fourth conductive line disposed on the second surface of the dielectric portion in alignment with the first conductive line, wherein the fourth conductive line connects the fourth terminal to the second portion of conductive material in the second passage.

**9.** An apparatus for interconnecting electronic components, the apparatus comprising:

a non-conductive portion having a first surface facing opposite to a second surface;

a first passage formed through the non-conductive portion at a first oblique angle relative to the first surface of the non-conductive portion;

a first portion of conductive material at least partially filling the first passage after forming the first passage;

a second passage formed through the non-conductive portion, wherein the second passage is non-parallel to the first passage, and wherein the second passage is formed through the non-conductive portion at a second oblique angle relative to the first surface of the non-conductive portion;

a second portion of conductive material at least partially filling the second passage after forming the second passage;

first means disposed on the first surface of the non-conductive portion for electrically connecting the first portion of conductive material to a first electronic component;

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second means disposed on the second surface of the non-conductive portion for electrically connecting the first portion of conductive material to a second electronic component;

third means disposed on the first surface of the non-conductive portion for electrically connecting the second portion of conductive material to a third electronic component, wherein the third means is offset from the first means in a first direction; and

fourth means disposed on the second surface of the non-conductive portion for electrically connecting the second portion of conductive material to a fourth electronic component, wherein the fourth means is offset from the second means in a second direction opposite to the first direction.

**10.** The apparatus of claim 9

wherein the second means is laterally offset from the first means, and wherein the first portion of conductive material directly connects the first means on the first surface to the second means on the second surface.

**11.** The apparatus of claim 9 wherein the first means include a first conductive line disposed on the first surface of the non-conductive portion, wherein the second means include a second conductive line disposed on the second surface of the non-conductive portion, and wherein the first conductive line is vertically misaligned relative to the second conductive line.

**12.** The apparatus of claim 9 wherein the non-conductive portion includes a silicon substrate.

**13.** The apparatus of claim 9 wherein the non-conductive portion includes a fiber-reinforced substrate.

**14.** The apparatus of claim 9 wherein the first means include a first conductive line disposed on the first surface of the non-conductive portion, wherein the second means include a second conductive line disposed on the second surface of the non-conductive portion, wherein the third means include a third conductive line disposed on the first surface of the non-conductive portion in alignment with the second conductive line, and wherein the fourth means include a fourth conductive line disposed on the second surface of the non-conductive portion in alignment with the first conductive line.

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